Physics 215 - Experiment 2

Vector Addition

Fig. 2-1 Force Table

EQUIPMENT

Force Table

4 Pulleys
4 Mass Hangers
Masses
Protractor
30-cm Ruler
Two-Force Card
Three-Force Card
Color Pencils
Graph Paper

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Vector Addition

Advance Reading
Urone, Ch. 3-1 through 3-3.

Objective
The objective of this lab is to study vector addition by the parallelogram method and by the component method and verify the results using the force table.

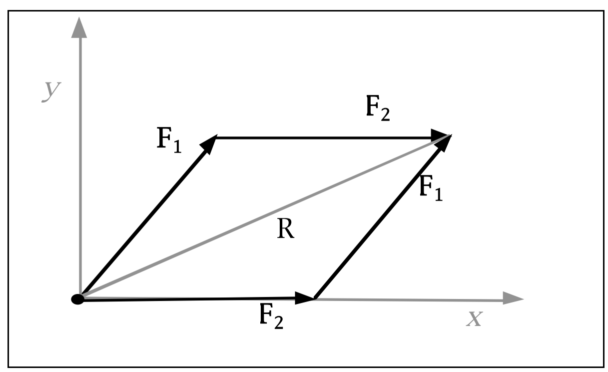
Theory
Vectors are quantities that have both magnitude and direction; they follow specific rules of addition. Force is a vector, so we will use a force table to verify the results of vector addition. The table is a circular steel table that has the angles 0^o to 360^o inscribed on the edge. (See Fig. 2-1.) To use the force table, pulleys are placed at the angles specified by the force cards, with the strings attached to the center ring running over the pulleys. Masses are placed on mass hangers attached to the end of the strings to provide the force needed. By adding the vectors, the resultant vector is found. To balance the force table, however, a force that is equal in magnitude and opposite in direction must counter-balance the resultant. This force is the **equilibrant.** For example, if a 10 N force at 0^o and a 10 N force at 90^o are added, the resultant vector has a magnitude of 14.7 N at 45^o. The equilibrant has the same magnitude, but the direction is $180^o+45^o=225^o$.

PROCEDURE
Note: *Do Parts 1a, 2, and 3 for* two forces*, then Parts 1b, 2, and 3 for three forces.*

PART 1a: Graphical Method - Parallelogram Method (2 vectors)

1. Use Cartesian coordinates and color pencils to draw a directed line segment from the origin for each of the two forces provided. Let 1 cm = 1 N. Label one force $\mathbf{F_1}$ and the other $\mathbf{F_2}$.

2. **Lab partner one**-Draw $\mathbf{F_2}$ from the tip of $\mathbf{F_1}$. (See Fig. 3-2.) In Fig. 3-2, the vectors $\mathbf{F_1}$ and $\mathbf{F_2}$ are added together graphically to get the resultant, **R**, which is drawn *from the origin* to the point where the two vectors meet.
   Lab Partner two-Reverse the order of addition (i.e., draw $\mathbf{F_1}$ from the tip of $\mathbf{F_2}$ and then draw resultant).
3. Measure and record **R** (the angle and the magnitude of the resultant vector) using the protractor and ruler. Be sure and note the uncertainty of length and angle.



PART 1b: Graphical Method – Tail-to-Tip Method (3 or more vectors)

4. Draw a directed line segment from the origin for each force.

5. On a separate sheet of the graph paper redraw origin and axes. Select force 1 to start. Draw force 2 from the tip of the force 2, then force 3 from the tip of force 3. **Your partner** should start

with force 3 (then force 2 and then force 1) The resultant is drawn *from the origin* to the tip of the last force drawn. Measure length of **R** and its angle .

PART 2: Analytical Method

If the direction of a vector is measured *from* the positive x-axis in a counter-clockwise direction (standard procedure) then the following is true:

$F_x = F \cos\theta$ (Eq. 3-1)

$F_y = F \sin\theta$ (Eq. 3-2)

$\theta = \tan^{-1}(F_y/F_x)$ (Eq. 3-3)

When you add vectors, they equal a **resultant**, **R**. To add vectors mathematically, you need to first determine the components of each vector. Then add: all the x-components (F_x); all the y-components (F_y).

$R = \sqrt{F_x^2 + F_y^2}$ (Eq. 3-4)

$\theta = \tan^{-1}(F_y/F_x)$ (Eq. 3-5)

6. Calculate the magnitude and direction of **R** for your forces. N*ote:* Verify the quadrant. Your calculator will give you only one of two possible angles.

PART 3: Force Table

7. If values from Part 1 and Part 2 agree, use the force table to verify the answer from Part 1. First, level the force table using the leveling screws and the carpenter level.
8. Place pulleys at the positions specified by the force card; add masses to provide the forces. Let 100 grams = 1N. If the values obtained for the resultant are correct, then the equilibrant will balance the system and the ring will be centered on the pin.
9. Add the equilibrant force to the table.

10. To determine the uncertainty in the magnitude and direction of the equilibrant:

    δm - add mass to the equilibrant until the ring shifts, but does not touch the pin.

    $\delta\theta$ - adjust the position (θ) until the ring shifts, but does not touch the pin.

Questions

1. If five vectors were added tail-to-tip and they ended up where they started from, what would be the magnitude and direction of **R**?

2. Is the graphical or force table method more accurate? Why?

3. Were your results from part 1a consistent with the commutative law of vector addition (i.e., was $\vec{F}_1 + \vec{F}_2 = \vec{F}_2 + \vec{F}_1$)?

4. Were your results from part 1b (i.e., using 3 forces) consistent with the associative law of vector addition(i.e., was $(\vec{F}_1 + \vec{F}_2) + \vec{F}_3 = \vec{F}_1 + (\vec{F}_2 + \vec{F}_3)$?